Standard Drawing Report

Date: November 2, 2021

Technical Owner: Traffic – Scott Batson, P.E.

Standard Drawing No. P-442 **Calculation Book No.** 442

Drawing Title: Multi Cushion Speed Bumps

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REGISTERED PROFESSIONAL ENGINEER
17050PE
Digitally Signed
OREGON
MARCH 15, 1994
SCOTT M. BATSON
Expires 12/31/23

Background Information, Including Reference Material:

Appendix A: Split Speed Bump, Kathy Mulder, PE, 1998

Appendix B: The Influence of Traffic Calming Devices on Fire Vehicle Travel Times, Portland Bureau of Transportation, 1996

Appendix C: A Brief History of the Traffic Calming Program in Portland.

Appendix D: Offset Speed Tables for Reduced Emergency Response Delay, Scott Batson, 2004

Appendix E: Speed Cushion Redesign MOU, Portland Bureau of Transportation, 2019.

Appendix F: Speed Cushion Design Summary, Scott Batson, 2011

Assumption Made:

The 14' speed bump is adapted to reduce traffic speeds on Major Emergency Response (MER) and Secondary Emergency Response (SER) routes. The original 14'foot speed bump profile is retained, and gaps are created between bump sections (a.k.a. cushions) that permit fire trucks to traverse the device with minimal delay.

Design Narrative:

In 1991 the City of Portland embarked on a program to reduce vehicles speeds on certain streets due to vehicle diversion from congested streets. The 14' long bump that is 3 inches high in the middle produced an 85th percentile speed for passenger cars and light vans of between 18 and 28 mph, depending on the spacing of the bumps. Local streets had an assumed speed limit of 25 mph unless otherwise posted, but now have an assumed speed of 20 mph.

The City of Portland Fire Bureau tested the 14' bump and said the maximum comfortable speed for their vehicles over the bump was 20 mph. Subsequent testing found the 14' speed bump could cause up to 11 seconds of delay to a fire truck for each bump constructed. This eventually resulted in the prohibition of speed bumps on designated primary emergency response routes.

PBOT continued to pursue traffic calming for designated emergency response routes and reached agreement with PF&R in 2017 to test speed cushions on Portland streets. Speed cushion sizing was developed based on measured space between the dual wheels of two representative Portland Fire and Rescue heavy vehicles, Truck 1 and Ladder 1. Field testing showed the original layout accommodated the dual rear tires of fire trucks.

PBOT and PF&R revisited the design in 2019 to enhance fire vehicle access, and address constructability concerns, and created a Memorandum of Understanding (MOU) to document the agreement. The use of multi cushion speed bumps was adopted in the updated 2035 Transportation System Plan.

While this report deals with the development of the bump itself, it is critical that the engineer takes care in the placement of the bumps along the roadway according to current practice. The reports in the calculation book goes into detail about issues to consider when placing more than one bump near each other.

APPENDIX A

Split Speed Bump

Kathy Mulder, PE, City of Portland, Oregon, Traffic Calming Program*

January, 1998

Introduction
History / Problem
Test and Test Plan
Conclusions and Recommendations

Introduction

Speed bumps have been found to be very effective at slowing traffic on residential streets throughout the City of Portland. City residents have embraced these devices as a means to slow traffic and enhance their livability.

The speed bump programs began in 1992 after several months of test and evaluation with two bump designs. The 14 foot speed bumps, only used on Local Service Streets (the lowest classification of streets in the City), slow passenger cars and light vans so that the 85th percentile speed along the street is between 24 and 28 mph. The 22 foot speed bumps allow an 85th percentile speed of 29 to 34 mph.

The Fire Bureau expressed concern that the 22' speed bumps are slowing their trucks and engines causing a negative impact on the Fire Bureau's 4 minute "fire response time"goal. In a series of several speed bumps on primary fire response routes, valuable time is lost, endangering public safety. We needed to develop a solution that would address both aspects of public safety, rapid response by Emergency Services and traffic calming for residential streets.

History / Problem

In 1991 the City of Portland Bureau of Traffic Management undertook a study of speed bumps (humps) in response to public demands for some respite from the excessive and continual increase of traffic speeds. As the result of two years of testing, speed bumps became a standard 'tool' for addressing the problem of speeding on Portland's residential streets. In Phase III of the original 1992 speed bump tests, the " Fire Bureau indicated a maximum comfortable speed of 20 mph for the 14'...speed bump and 25 mph for the 22'...speed bump"**.**

The 14' speed bump was adopted for local service streets that do not have transit or are not a primary fire response route. The 22' speed bump is designed for streets with high volumes of traffic, and those that are transit or primary fire response routes.
The Traffic Calming Program has been installing speed bumps since 1992, and in the fiscal year 1995-96, installed more than 100 new speed bumps. With so many bumps installed, and hundred's of streets on waiting lists, the Fire Bureau and the Bureau of Traffic Management became concerned about a "cumulative effect", or how several speed bump streets along any emergency route may impact the response time.

The goal of the Portland Bureau of Fire and Emergency Services is a response time of 4 minutes or less on 90% of emergency calls. A study was undertaken to quantify the effects of speed bumps on emergency vehicles. Measurements found that the amount of the time increase was dependent upon the type of vehicle and the type of traffic calming. Rescue vehicles were not slowed at all over the 22' bumps, while trucks and engines were slowed as much as 9 seconds per bump.

It was decided that an "emergency response route" street classifications would need to be developed, similar to the City's existing traffic street classifications[2], before any more traffic slowing devices could be placed on emergency response routes. This process of developing an emergency response route street classification and policies is a long and detailed task that can take several years to complete. All projects planned for streets currently used as primary routes by the Fire Bureau were put on hold until the classification process was completed.

In the meantime, excessive vehicle speeds continue to threaten public safety and neighborhood livability, and a great number of speeding problems are found on streets that also serve as primary response routes. The Traffic Calming Program needed a device that would both accommodate the Fire Bureau vehicles, and still slow speeding motorists.

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Test and Test Plan

Since fire and emergency vehicles are allowed, by law, to use any portion of the street they need when on an emergency response run, we began with the concept of a chicane using two halves of a 22' speed bump separated by enough distance so that the emergency vehicle with the least amount of maneuverability could go through the chicane at approximately 20 mph.

Phase I

A Traffic Calming engineer and a Fire Bureau battalion chief used cones to build a simulation of the test device at the Fire Bureau Training Center. The vehicle selected by the Fire Bureau for testing was the vehicle with the least amount of maneuverability. The truck was 39 feet long, 8 feet, 4 inches wide, with a wheelbase of 18 feet, 6 inches. The street width used was 40'.

RESULTS OF PHASE I

In August of 1996, trial runs were conducted in the Fire Bureau Training Center lot, in a wide area of asphalt. A street segment and speed bump halves were outlined with cones, and runs were made through the split bump halves. After several runs, it was decided that the distance between the two lane bump halves needed to be at least 28 feet for the vehicle to maneuver through at or near 20 mph. Preliminary drawings of the new device were made and a field test was planned.

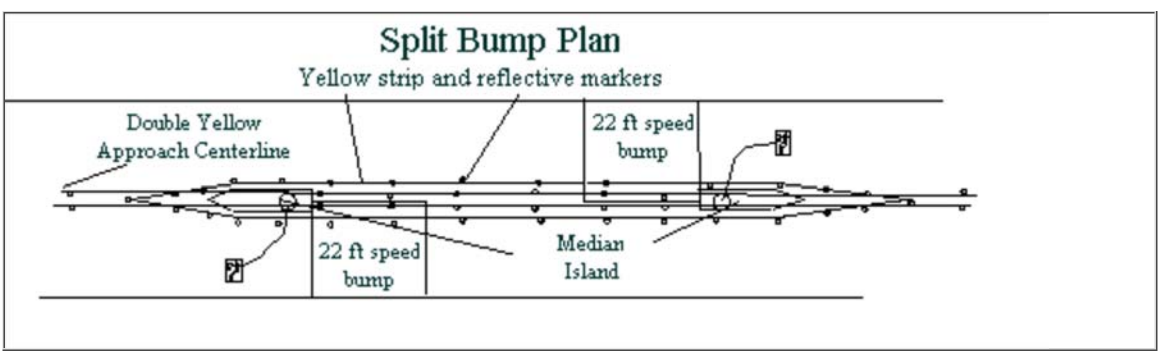
Phase II

Part 1 An actual street test location was selected that was part of an existing traffic calming project: SE Market Street between SE 117th and SE 112th Avenues. This street is 42 feet wide, has no horizontal curves, and the visibility along the street is excellent. This segment of SE Market is defined by a signal at SE 112th and an all-way stop at SE 117th.

Photos

The nearby fire station was notified and asked to make a few practice runs through the off-set speed bump and offer any suggestions they felt were appropriate.

The device was placed approximately 200 feet west of the all-way stop. The first part of the testing was for safety. Concerns of whether automobile drivers would violate the device and chicane between the bumps were raised. Twenty-four hour time lapse video equipment was placed to record driving patterns over the bump.



Part 2 This part of the initial testing was to determine if, and how fast fire vehicles were able to drive around the two bump halves. The largest Fire Bureau vehicles from from the nearby station was used for the short test.

Part 3 The final part of Phase II was to place another split speed bump device approximately 600 feet west of the original device to determine the effect on speeds the two devices have in combination.

Total slowing effect on fire vehicles was tested. This was a controlled test that matched the original test that determined the time lost by speed bumps on fire vehicle response times.

RESULTS OF PHASE II

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The 24 hour time-lapse video showed that drivers did not swerve into the oncoming lane to avoid the speed bump half in their lane. The temporary concrete medians and signs placed in advance of each bump half seemed to keep drivers in their own lane and over the speed bump. Dense centerline striping and raised reflective pavement markings gave an illusion that a median continued the entire distance between the bump halves. Subsequent 24 hour time-lapse video showed no indication of confusion on the part of the drivers, nor any violations of drivers trying to avoid the device at any time.

The results of the Fire Bureau vehicle testing were favorable. The vehicles were able to travel through the "chicane" at 17 to 21 mph. They indicated that the speed was quite satisfactory, and that this maneuver is no different than weaving around cars.

Concern was raised that a car may stop in the middle of the gap between bumps while the emergency vehicle approaches. There was fear that this device might prevent drivers from pulling off to the right when the emergency vehicles are running. Parking removal would alleviate this problem by providing an available refuge for cars pulling off to the right. If a car does stop in the middle of the device and blocks the fire vehicle pathway, the Fire Bureau decided that they would just go over the 22' bump. An occasional 22' speed bump does not create serious delay problems for them.

It was determined that parking removal would be necessary for the Fire Bureau to perform the chicane maneuver. Parking was removed on both sides of Market Street opposite each bump half.

Since it was found that the general public is willing to stay to the right of the centerline, two adjustments were considered to the companion device to be installed approximately 600' from the first device.

- The first adjustment was to make the approach islands shorter. It appeared that the "Keep Right" sign was enough to win driver compliance, and that the 20' island could be made smaller, just enough to place the sign.
- The second adjustment was to widen the gap between the two bump halves. This was done to explore how far apart the two bump halves can be and still maintain driver compliance on a straight stretch of street.

With the second device in place (installed 4/11/97) the street was measured for overall slowing effect. The effect on the 85th percentile speed was impressive. While control locations along Market Street (106th, 110th, 122nd) had no change in their 85th percentile speeds, the 85th percentile speed at the location between the two off-set bumps (114th) dropped from 37 mph to 26 mph.

85th Percentile Speed Changes on SE Market Street

Market St. Location	**85th %ile Before Test (mph)**	**85th %ile with One Split Bump in Place**	**85th %ile with Two Split Bumps in Place**
East of 106th Ave	40	36	37
West of 114th Ave*	37	35	26
West of 122nd Ave	34	33	34

Table 1 * Between the two bump locations

Emergency vehicles ran timed tests through both of the new split bumps to determine the time lost by each vehicle. A truck and an engine were supplied for the test. These are the vehicles that had the greatest delay per device during the original testing of the other traffic calming devices.

Both vehicles were able to travel the length of the street at speeds between 29 and 31 mph. The vehicle speeds through the 50 foot off-set spacing were 26 mph to 30 mph. Between the 28 foot off-set spacing, speeds were 20 mph to 26 mph. It was found that the actual time lost was no more than 1 to 2 seconds for the largest of the vehicles.

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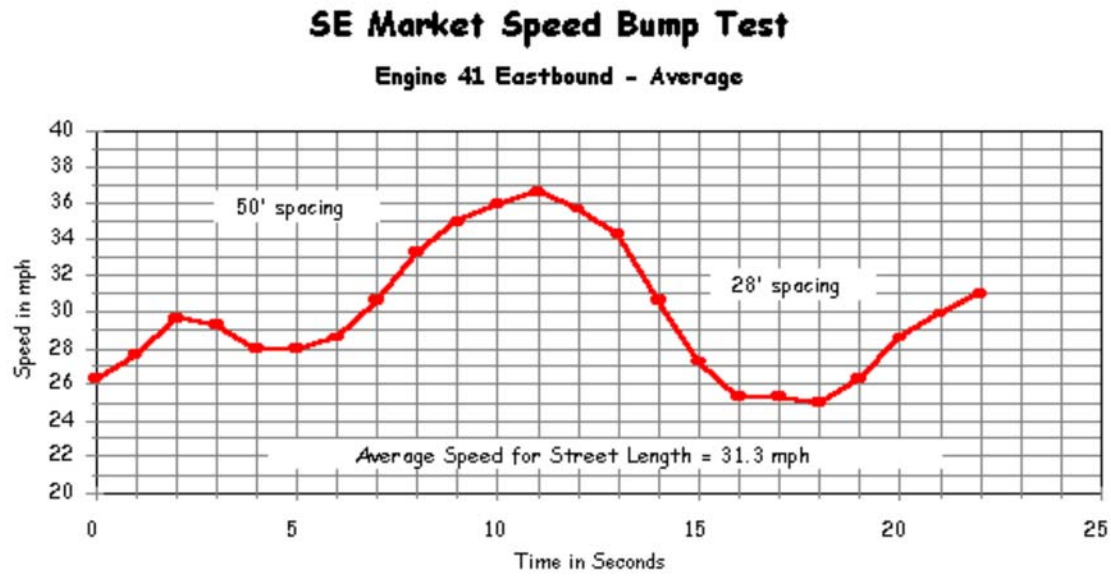
SE Market Speed Bump Test
Engine 41 Eastbound - Average
50' spacing
28' spacing
Average Speed for Street Length = 31.3 mph
Speed in mph
Time in Seconds
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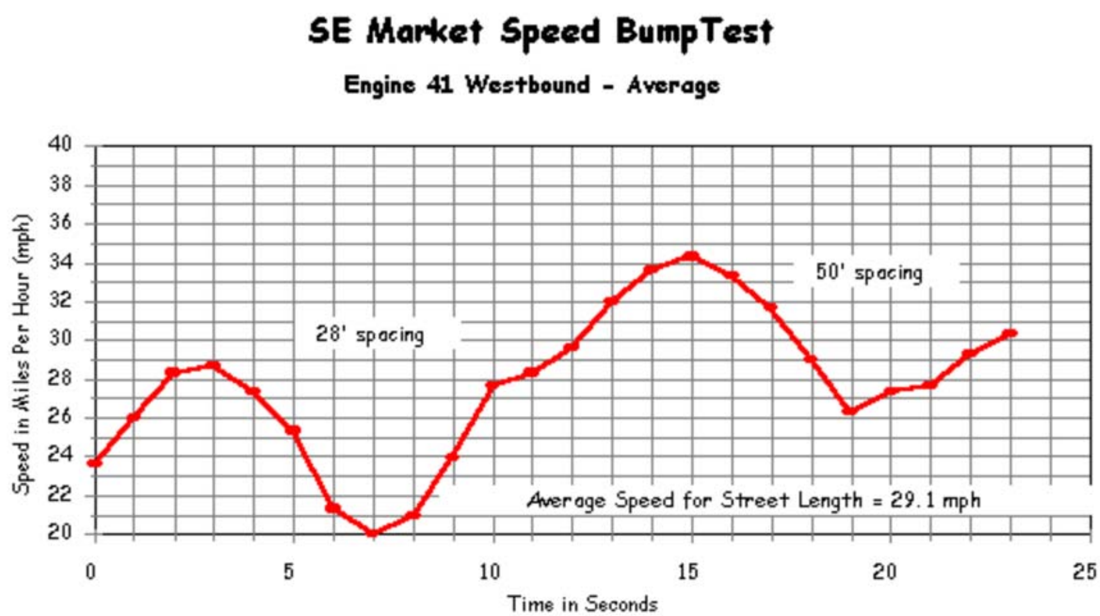
SE Market Speed BumpTest
Engine 41 Westbound - Average
28' spacing
50' spacing
Average Speed for Street Length = 29.1 mph
Speed in Miles Per Hour (mph)
Time in Seconds
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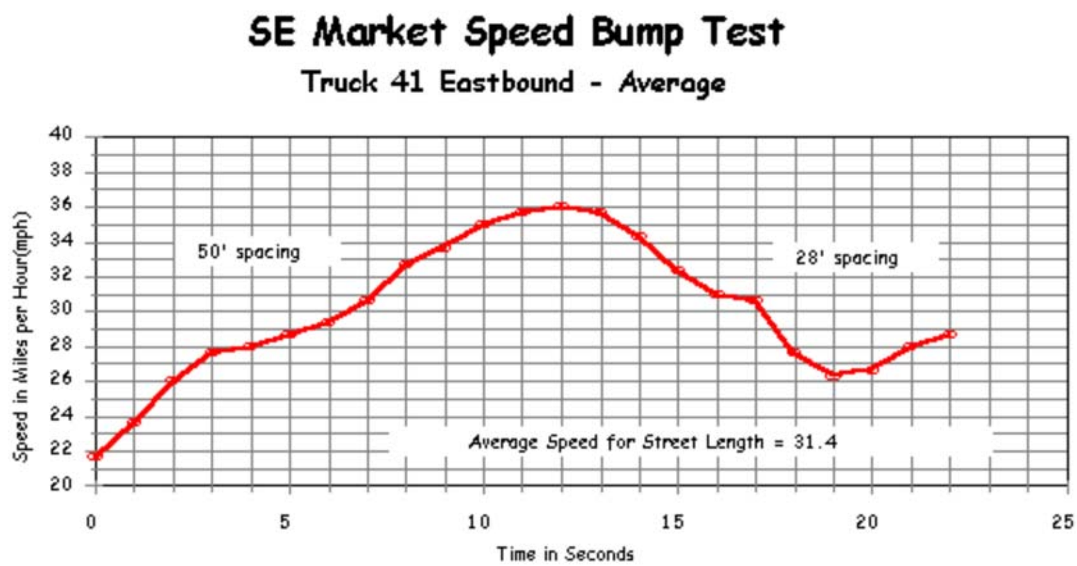

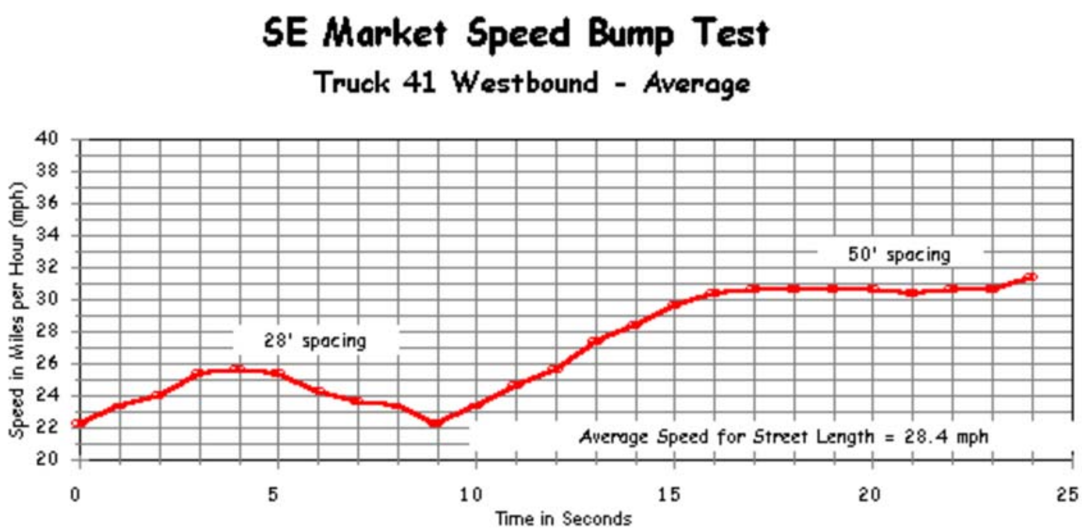

The Fire Bureau is satisfied with the results and have no objections to limited use of this device. They asked that the distance between bump halves be greater than the original 28 feet. 50 feet was set as the standard minimum distance between the bumps. The distance may be extended, however, driver compliance must be maintained. It is hoped that the bump halves will be able to function as individual devices.

In reviewing the data for the test, it was noted that the slowest speeds, and therefore the most time lost, were at the off-set speed bump with the 28' spacing The speed for the off-set speed bump with the 50' spacing never went below 25 mph.

Since the Fire Bureau believes that 25 mph is a reasonable speed for their vehicles on a Local Service street, it was concluded that the split bump, as it was designed with the 50' spacing, would meet their needs.

Based on the results of Phase I and II of the Off-Set Speed Bump Test, a third phase was initiated to determine some of the limitations of this new device.

Phase III

The third phase of the testing included the split speed bump in combination with other traffic calming devices, and to test this combination on a street narrower than 42'. The most common street width in the City is 36'. SE 17th

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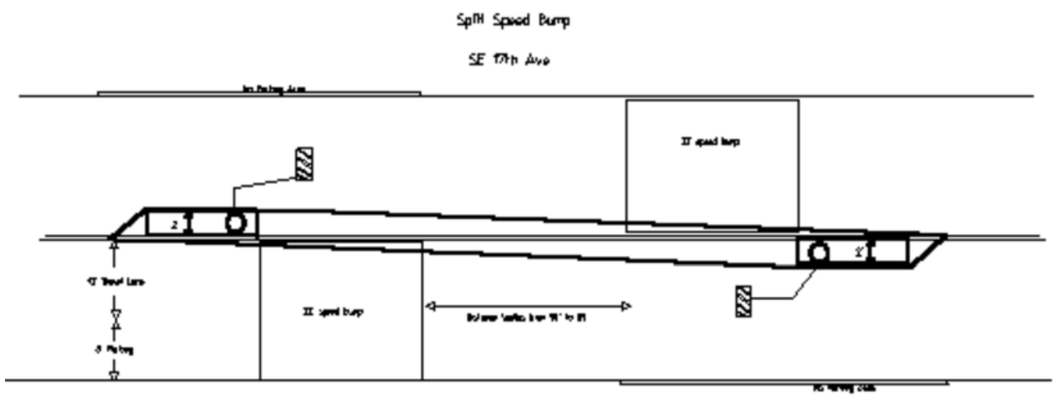
Avenue between SE McLoughlin Blvd and SE Tacoma St. was chosen for this test. It is 36 feet wide, with parking allowed on both sides of the street. 85th percentile speeds along this 11/2 mile section measured from 37 mph to 39 mph. The speed limit is 25 mph.

A Traffic Committee consisting of area residents interested in solving the traffic problems on SE 17th established speed reduction as one of its primary goals. They circulated a petition for a test, and a majority of residents on SE 17th signed the petition.

The design on the split bumps for this narrower street required some lane adjustments to maintain a minimum 10' lane through the device. Because of the width restriction on SE 17th, parking was removed for 30' opposite each of the split bumps. This incorporated both the 22' length of the bump half, and 7 feet for the approach island. These islands were only 2 feet wide, and set in such a way as to maintain the 10' travel lane. The distances between the bumps ranged from 50' to 85'.



Two issues arose. The parking removal, necessary for the Fire Bureau vehicle moves and lane widths for the buses. While the bus system in Portland, Tri-Met, felt that their buses could operate satisfactorily on the 10' lane, the day following the device installations Tri-Met re-routed the bus line on SE 17th west 1 block to SE Milwaukie (a Neighborhood Collector). Tri-Met contended that the parking removal was insufficient for their needs. 10 to 30 feet of additional parking was removed to allow the buses the additional lane width they required.

Tri-Met had additional concerns about the street designs. Their concern was that if a larger vehicle were to park at the edge of the "no parking" areas, that they might not be able to get through the device. This "tight area" was at the concrete median in advance of the bumps.

Tri-Met concluded that a 10' travel lane is not enough for them to maneuver their buses down the City Streets. They require the option of crossing over the yellow centerline in cases where large vehicles were parked along the street. It was decided that the split speed bumps would be removed, and other methods of traffic slowing would be investigated.

Speed and volume data were collected on SE 17th as well as parallel streets (including SE Milwaukie). The results indicated that the 85th percentile speed had dropped 5 to 6 mph on SE 17 with the speed bumps. In addition, speeds were also reduced on SE Milwaukie, most likely due to the increase in volume.

85th Percentile Changes with Split Speed Bump in Place

Street	**Location**	**85th %ile Before**	**85th %ile After**	**Change**
Milwaukie	north end	37 mph	36 mph	-1 mph
	south end	34 mph	28 mph	-6 mph
SE 17th	north end	38 mph	32 mph	-6 mph
	south end	37 mph	32 mph	-5 mph
SE 18th	north end	20 mph	21 mph	1 mph

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	south end	26 mph	27 mph	1 mph
SE 19th	north end	27 mph	25 mph	-2 mph
	south end	28 mph	27 mph	-1 mph
SE 20th	north end	22 mph	25 mph	3 mph
	south end	24 mph	24 mph	0
SE 21st	north end	25 mph	25 mph	0
	south end	25 mph	27 mph	2 mph
SE 22nd	north end	28 mph	27 mph	-1 mph
	south end	32 mph	31 mph	-1 mph

Table 2

No violations of the devices were observed. Drivers either slowed, or chose another route for their trips.

A comparison between the total area volumes before and after the split speed bumps were installed revealed an overall net loss of traffic volume at both the north end of the area and a greater volume reduction at the south end of the area. They also reduced the amount of large truck traffic that had used SE 17th as a cut-through to avoid the business areas of NE Milwaukie St.

Volume Change with Split Speed Bumps in Place

x-str	**Milwaukie**	**SE 17th**	**SE 18th**	**SE 19th**	**SE 20th**	**SE 21st**	**SE 22nd**	**Total**
Ellis	1184	-2094	0	18	52	26	62	-752
Rex	1568	-3136	18	-26	-36	-101	-55	-1768

Table 3 all numbers are in vehicles per day (vpd)

Since the split bumps have been removed, residents of SE 17th report that the speeds have increased and large trucks are again using their streets.

Conclusions and Recommendations

The split speed bump was found to effectively slow traffic speeds without delay to emergency vehicles. In both of the tests, speeds were reduced and Fire Bureau quick response time was maintained. The larger distances between each of the bump halves does not seem to influence driver behavior. Especially on high volume streets, drivers showed no tendency to cross over the center line to avoid the bump.

The test on SE 17th showed that the additional parking removal needed for bus operation conflicted with the neighborhoods need for on-street parking. Tri-met tells us that if more parking could have been removed for the bumps, transit buses would have had no difficulty negotiating them on this 36' wide street.

Since parking removal is necessary for these devices to operate well on the street widths tested, they should not be considered for streets where on street parking is important. The advantages of slower vehicle speeds needs to be weighed against the residents needs for on street parking with the final decision to be made by the residents.

*Kathy Mulder, PE, is a senior engineering associate with the City of Portland, OR, Bureau of Transportation System Management, Traffic Calming Program and an Associate Member of ITE.

End Notes:

1. Speed Bump Evaluation Status Report, City of Portland, OR, Bureau of Traffic Management; June 1992.

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2. Transportation Element of the Comprehensive Plan, City of Portland, OR Department of Transportation; June 1996.

The Influence of Traffic Calming Devices on Fire Vehicle Travel Times
January 1996

Portland Bureau of Fire, Rescue and Emergency Service 55 SW Ash Street Portland, OR 97204	**Traffic Calming Section Bureau of Traffic Management** **Portland Office of Transportation** 1120 SW Fifth Avenue, Room 730 Portland, OR 97204

INTRODUCTION

Traffic calming devices are used on Portland's neighborhood streets when traffic conditions are out of character with their adjacent residential, institutional, and recreational land uses. Calming devices are used to slow vehicle speeds; to encourage the use of more appropriate streets for through trips; and to enhance pedestrian, bicycle, and transit safety. The devices have proven to be effective without significantly impacting convenience, mobility, and travel time for drivers. At the same time certain devices affect the speed of various fire vehicles and may increase overall response times.

During the Fall of 1995 the City's Fire Bureau and Bureau of Traffic Management conducted a thorough data collection effort to help quantify the relationship between three types of traffic calming devices and fire vehicle travel times. Different types of fire vehicles were driven on streets calmed with traffic circles, 22-foot speed bumps, and 14-foot speed bumps. Figures 1, 2, and 3 illustrate the three devices. Table 1 lists basic information about the types of fire vehicles used in this study.

PURPOSE

The purpose of this paper is to present how speed bumps and traffic circles affect fire vehicle travel times. This paper describes how the data was collected and analyzed, presents the findings, and goes on to recommend additional areas in need of research.

RESEARCH METHOD

The testing considered four variables that influence the speed at which a fire vehicle can be negotiated around traffic circles or across speed bumps. The variables tested are: the driver, the type of fire vehicle, the desirable vehicle speed, and the types of calming devices.

The data collection effort involved six fire vehicles of varying characteristics. Test runs were conducted on a total of six streets. Two streets had 22-foot speed bumps. Two streets had 14-foot speed bumps, and two had traffic circles. A total of 36 different drivers participated in the testing. The total number of test runs on each street was four per vehicle, or 24 runs per street. Each test run was video taped. The camera recorded the vehicle speeds that were detected and displayed by a radar gun. The time of day, to the nearest second, was superimposed on the recording.

Table 1. Fire Vehicle Specifications

Vehicle	Overall Length	Wheelbase	Weight (lbs)	Horse-power (HP)	Wt./HP Ratio (lbs/HP)	0-40 mph Accel. Time (sec)
Engine 18	29' 10"	15' 5"	34,860	185	188	19
Rescue 41	21'	11' 6"	na	185	na	12
Squad 1	27'	14' 6"	23,170	275	84	17

Truck 1	48'	21' 0"	53,000	450	118	20
Truck 4	57'	13' 0"	53,960	450	120	22
Truck 41	37' 6"	16' 9"	42,100	350	120	27

The speed and time information for each test run was transcribed from the video tapes to a spreadsheet. The information for each run was used to calculate the distance traveled after each second as well as the vehicle's distance from the starting line after each second of the run.
For various combinations of the four variables, the time needed to travel a length of street that had no calming device was compared to the time needed to travel the same length with a calming device. The time and impact distance required to decelerate from a desirable response speed, negotiate the calming device, and accelerate back to the original speed was determined from the data. The time required to travel the same impact distance without a calming device to influence the desirable response speed was calculated. The difference between the two travel times equals the delay associated with the calming device. This delay-per-device was calculated for all six vehicles as they negotiated every calming device on the six test streets. Delays-per-device were calculated for desirable response speeds of 25, 30, 35, and 40 mph.

FINDINGS

The results of the City's research are presented in Table 2, Table 3, and Table 4. Depending on the type of fire vehicle and the desirable response speed, the three devices were found to create a range of delays for each device as follows:

- 14-foot bumps: 1.0 to 9.4 seconds of delay per bump
- 22-foot bumps: 0.0 to 9.2 seconds of delay per bump
- Traffic circles: 1.3 to 10.7 seconds of delay per circle

The drivers' performances did not appear to significantly influence the results. Their choices of deceleration and acceleration rates as well as their choices of minimum speeds near the devices were very consistent.

CONCLUSIONS

The purpose of this paper was to show how speed bumps and traffic circles used in Portland affect fire vehicle travel times. The results provide quantitative data that can be used in the determination of the impacts of one or more traffic calming devices on fire response times along a given emergency response route. Additional information is necessary in order to make a complete assessment of these impacts. This includes: 1) the types of fire vehicles responding to emergencies; 2) the desirable and appropriate speed of fire vehicles at each of the calming devices located along the response route; 3) the geographical area that will be affected by any increase in delay to response times; and 4) the use of this route by fire vehicles given the likely demand for emergency services and the availability of good alternative routes.
A full assessment of the impacts on response times for a given set of traffic calming devices needs to be balanced with the benefits of traffic calming on reducing speeding problems and enhancing public safety and livability along neighborhood streets. This paper provides the initial quantitative data that is necessary to begin to weigh the pros and cons of traffic calming.

RECOMMENDATIONS

The City needs to pursue full assessments of the impacts of specific traffic calming projects, either planned or existing projects, on emergency vehicle responses. This assessment needs to consider all the necessary information as summarized above. The results of this assessment then needs to be compared to the benefits of the traffic calming project, especially the benefits to public safety.

Due to the City's desire to provide both fast response for emergency services and slower overall traffic speeds on neighborhood streets, a public process should be undertaken to address the trade-offs between these two community values and to provide policy direction for implementing traffic calming on a city-wide basis. This should be done by revising the Transportation Element to include a classification for emergency response routes.

Factors that may need to be considered in addressing any trade-offs are options to mitigate impacts on fire vehicle response times. These options include the use of traffic signal preemption devices, the locating of new fire stations, fire vehicle modifications to minimize weight-to-horsepower ratios, securing and cushioning certain pieces of equipment, and improving vehicle suspensions.

Table 2: Typical Impacts of 14-foot Speed Bumps on Emergency Vehicles

Bureau of Traffic Management
Portland Office of Transportation
City of Portland, Oregon
January 1996

Vehicle	Lowest Speed (mph)	Desirable Speed (mph)e	Travel Time Delay (seconds)	Impact Distance (feet)
Engine 18	13	25	2.3	236
	13	30	3.7	399
	13	35	5.2	581
	13	40	7.7	814
Rescue 41	17	25	1.0	147
	17	30	1.7	269
	17	35	2.9	483
	17	40	4.9	628
Squad 1	12	25	2.7	244
	12	30	4.1	436
	12	35	5.9	611
	12	40	8.3	852
Truck 1	11	25	3.4	269
	11	30	4.9	455
	11	35	6.6	646
	11	40	9.4	931
Truck 4	12	25	3.4	315
	12	30	4.9	485
	12	35	6.8	732
	12	40	9.1	1053
Truck 41	12	25	3.5	327
	12	30	4.7	472
	12	35	6.6	762
	12	40	8.6	1152

Lowest Speed: This is the lowest speed a vehicle travels when crossing a 14-foot speed bump.

Desirable Speed: This is the speed a driver might wish to travel if there were no speed bumps.

Travel Time Delay: This is the additional time required to travel to a destination due to a 14-foot speed bump's influence.

Impact Distance: This is the length of street where a given vehicle cannot be driven at the desired speed because of the speed bump's influence.

Table 3: Typical Impacts of 22-foot Speed Bumps on Emergency Vehicles

Bureau of Traffic Management
Portland Office of Transportation
City of Portland, Oregon
January 1996

Vehicle	Lowest Speed (mph)	Desirable Speed (mph)	Travel Time Delay (seconds)	Impact Distance (feet)
Engine 18	21	25	0.8	136
	21	30	1.7	323
	21	35	3.0	505
	21	40	5.0	752
Rescue 41	34	25	0.0	0
	34	30	0.0	0
	34	35	0.3	118
	34	40	1.5	263
Squad 1	24	25	0.4	80
	24	30	1.0	214
	24	35	2.1	433
	24	40	3.4	708
Truck 1	22	25	0.6	137
	22	30	1.4	320
	22	35	3.0	600
	22	40	4.9	885
Truck 4	16	25	1.8	254
	16	30	3.4	449
	16	35	5.9	674
	16	40	7.7	1039
Truck 41	14	25	3.0	316
	14	30	4.8	622
	14	35	7.2	912
	14	40	9.2	1322

Lowest Speed: This is the lowest speed a vehicle travels when crossing a 22-foot speed bump.
Desirable Speed: This is the speed a driver might wish to travel if there were no speed bumps.
Travel Time Delay: This is the additional time required to travel to a destination due to a 22-foot speed bump's influence.
Impact Distance: This is the length of street where a given vehicle cannot be driven at a given desirable speed because of the speed bump's influence.

Table 4: Typical Impacts of Traffic Circles on Emergency Vehicles

Bureau of Traffic Management
Portland Office of Transportation
City of Portland, Oregon
January 1996

Vehicle	Lowest Speed (mph)	Desirable Speed (mph)	Travel Time Delay (seconds)	Impact Distance (feet)
Engine 18	14	25	2.8	261
	14	30	4.3	489
	14	35	6.1	671
	14	40	8.5	814
Rescue 41	16	25	1.3	170
	16	30	2.3	301
	16	35	3.1	467
	16	40	5.1	612
Squad 1	17	25	1.2	172
	17	30	2.3	326
	17	35	3.7	501
	17	40	5.3	776
Truck 1	10	25	4.8	319
	10	30	6.4	524
	10	35	8.4	749
	10	40	10.7	1034
Truck 4	11	25	4.3	322
	11	30	6.2	549
	11	35	8.1	799
	11	40	10.3	1139
Truck 41	11	25	3.9	338
	11	30	5.2	555
	11	35	7.3	845
	11	40	9.2	1255

Lowest Speed: This is the lowest speed a vehicle travels when navigating around a traffic circle.
Desirable Speed: This is the speed a driver might wish to travel if there were no traffic circles.
Travel Time Delay: This is the additional time required to travel to a destination due to a traffic circle's influence.
Impact Distance: This is the length of street where a given vehicle cannot be driven at the desired speed because of the traffic circle's influence.

A Brief History of the Traffic Calming Program in Portland

- Arterial Streets Classification Policy, adopted in 1977 as the Transportation Element of the City's Comprehensive Plan, classifies streets by their intended type and function.

- A citizen survey reveals excessive traffic speeds and volumes as threats to feeling comfortable and safe as a non-motorized user of residential streets (early 80's).

- Origins of Comprehensive Plan Policies that directed improvements to Local Service and Neighborhood Collector Streets to reduce the negative impacts of excess traffic on residential livability and safety.

- The adopted update of the Arterial Streets Classification Policy contained the directive to create a "Neighborhood Traffic Program."

- Established the Neighborhood Traffic Management Program (NTMP) through Council Resolution No. 33706 on July 12, 1984, with one of the nation's first systematic approaches to the mitigation of residential traffic problems.

- Citizen Advisory Committee (CAC) appointed to undertake Neighborhood Traffic Management Plan (NTMP) evaluation and examine how well the NTMP objectives were being met.

- Technical Advisory Committee (TAC) also appointed to examine the effectiveness of traffic circles, impacts of traffic management devices on emergency vehicles, new devices and other issues of a technical nature.

- Initial tests on 12' speed bump design conducted in Willamette Park. Fire Bureau and other agencies participate in the test.

- Citizen concern regarding excessive traffic speeds and volumes on residential streets is reaffirmed in a 1992 Bureau of Transportation Management (BTM) survey of licensed drivers.

- Transportation Element (formerly ASCP) adopted by City Council in October 1992 included major policy change to expand the use of residential traffic management techniques to Neighborhood Collector Streets.

- Speed Bump Evaluation report published in June 1992 containing results of field studies on three bump designs: 12', 14', and 22'. Fire Bureau participated in field studies.

- Results of CAC and TAC evaluation of NTMP adopted by City Council

Resolution No. 35001, June 10, 1992.

- Significant changes resulted from the two reports: implementation of an Impact Threshold Curve for traffic diversion, modification of the ballot area, improvements to the visibility around traffic circles and the authority to use of speed bumps as traffic management devices.

- Peer Review Report on Portland's Traffic Circle Program found that reported accident rate had decreased by 28 to 84% at intersections where circles had been installed.

- CAC and TAC committees established to develop the Arterial Traffic Calming Program, the first program of its kind in the United States to address traffic management problems on Neighborhood Collector Streets with at least 75% residential zoning.

- City Council adopts Arterial Traffic Calming Program (ATCP) in September 1993 (Resolution #35183; September 22, 1993) Representative from Fire Bureau testified in support of this new program and indicated that the agency was satisfied that their concern about "cumulative impact" had been adequately addressed.

- Proposed changes to both the NTMP and ATCP were presented to and adopted by Council Resolution No. 35317, October, 19, 1994. ATCP and NTMP were consolidated and renamed the Traffic Calming Program (TCP); project planning process reduced; Streamlined Speed Bump Projects were proposed to address speeding problems on Local Service Streets with low traffic volumes and high speeds to reduce the backlog of requests; Residential Speed Bumps Purchase Projects were proposed to enable residents on some Local Service Streets to pay for speed bumps.

- 1995/1996: BTM and Fire Bureau conducted field studies of five representative fire response vehicles with traffic circles and speed bumps, determining typical slowing caused by each device.

- 1996: As a compromise with the Fire Bureau, Streamlined Speed Bumps and Residential Purchase projects were restricted to Local Services Streets that do not appear on the Fire Response Routes map, cutting the pool of eligible streets almost in half, until an official Major Emergency Response route classification and map is added to the TSP (Completed in 1998).

- Review of eight TCP projects found reported accidents reduced by 45% at intersections treated with traffic circles. Review of 17 projects involving both traffic circles and speed bumps indicated that the overall accident frequency was reduced by 32% for the length of the street treated. On streets where speed bumps have been installed, an overall average speed reduction of 8 mph has been produced.

- In 1997 PBOT and Portland Fire and Rescue (PFR, former Fire Bureau) began testing 'fire friendly' offset speed tables (with approach islands) to determine the parameters for construction and to reduce delay for the largest of the fire vehicles. While tests were conducted on City streets, and the estimated delay was reduced from 10 seconds per speed table to 2 seconds per offset speed table, no officially approved device was adopted.

- 1999: Low volume Neighborhood Collector streets were approved to purchase simple speed bump projects under the Residential Speed Bump Purchase Program by City Council.

- Portland Safe Routes to School (SR2S) began to develop programming in 2000, when the national conversation began with the funding of the Marin County program and the Oregon Walk + Bike to School committee was formed. The City of Portland took a step toward formalization when the State of Oregon passed House Bill 3712 (known as the 'Safe Routes to School Bill') in 2001. To date, over eighty elementary schools have been served and over forty have ongoing education programs.

- In 2001, PBOT and PFR again tested speed cushions and the offset speed table design, this time without the leading island. With an island, fire vehicles were required to drive in the opposing lane to go around the devices. Without the islands, fire vehicles only had to straddle the centerline. 22-foot speed cushions did not appear to have any effect on standard vehicle speeds. No device was approved or tested on City streets upon completion of these tests, though devices constructed in Beaverton were evaluated.

- 2003: Community and School Traffic Safety Partnership (CSTSP) created.

- 2004: Subsidized Residential Speed Bump Purchase projects authorized where the City funds 60% of the project costs for low volume Local Service streets with approved petitions, or low-volume Neighborhood Collector streets with approved petitions that also have Neighborhood Association endorsement.

- 2005: Safe Routes to School (SR2S) Program engineering evaluations begin. Thirty-two schools have had engineering evaluations.

- 2006/2007: Traffic Calming Program mothballed. City funding for traffic calming is reduced to only those projects that are part of a larger programmatic goal, such as Safe Routes to School, Neighborhood Greenways.

- 2009: Initiation of new bike classification – Neighborhood Greenways (NGs) – and goals that includes traffic calming to achieve 20 mph along the project street and diversion to achieve traffic volumes below 1,000 vehicles per day.

- 2010: Adopted MUTCD Option A pavement marking for speed bumps.

- 2011: PBOT and PFR were directed to evaluate and test a 'fire friendly' traffic calming device. PBOT agreed to evaluate 14-foot speed cushions (a speed bump with channels for fire vehicle tires), and after an initial test at the PFR training facility, speed cushions were installed on NW Cornell, between Lovejoy and the first tunnel, replacing the existing speed tables. PBOT also changed the design on SW 51st, Maplewood to Multnomah, from speed bumps to speed cushions at the request of PFR. Tests show that it is likely that speed reductions to near 30 mph are probable, but reductions to near 25 mph will be difficult. Also, the sizing of the cushions has not been finalized.

- 2011: Legislative authority (HB 3150) to reduce neighborhood greenway streets to 20 mph under certain conditions.

- 2012(?): The Community and School Traffic Safety Partnership (CSTSP, formerly Traffic Calming Program) is merged with Transportation Options to become the Active Transportation and Safety Division.

- 2013: Funding for approved neighborhood greenway projects ceases as of July first. Current approved projects and pending work is placed on hold. Traffic calming for Safe Routes to School and Bike Lanes is dependent on Federal funding.

- 2015: Completion of the Neighborhood Greenways (formerly Bike Boulevards) Assessment Report that establishes standards for auto speed and volume (daily and peak hour) and auto speed on designated greenway streets. Opens up such streets for internal diversion; identifies five legacy boulevards for upgrading to current standard.

- 2015: City Council adopts Vision Zero (June).

- 2016: On May 17th, Portland voters passed Measure 26-173, Portland's first local funding source dedicated to fixing our streets. Measure 26-173 will raise an estimated $64 million over four years. In the same month, the Portland City Council also passed the Heavy Vehicle Use Tax, a measure that will generate an estimated additional $10 million over four years. Funding is identified for paving and maintenance, Safe Routes to School, Neighborhood Greenways, crossing improvements, and protected bike lanes.

- 2016: Vision Zero action plan adopted (December).

- 2017: Portland gains authority to lower speed limit to 20 mph on non-Arterial (FFCS) streets. 25 mph limit reserved as lowest posted limit on MER routes.

- 2018: Secondary Emergency Response (SER) routes added with the update of the Transportation System Plan. Speed cushions permitted on SER without Portland Fire and Rescue permission. Speed cushions permitted on MER with permission.

Estimate of Traffic Calming Built – 9/26/18

Device	Number	Note
12-foot Bump	13	
14-foot Bump	1535	
22-foot Table	294	
22-foot Raised Crosswalk	45	Same profile as Speed Table
14-foot Cushion	42	Same profile as Speed Bump
Cul-de-sac/Dead End	16	
Diagonal Diverter	4	
Median Barrier	6	
Mini-Roundabouts	1	Test object, circular Speed Table
Pedestrian Refuge Island	119	
Roundabout	3	
Semi-diverter	28	
Traffic Circles	71	
Truck Trap	1	Access management

Offset Speed Tables for Reduced Emergency Response Delay

ITE Technical Conference, March 2004, Irvine, California

Scott Batson, PE

ABSTRACT

With the advent of speed humps (a.k.a. modern speed bumps) to reduce vehicle speeding on residential streets has come the unwanted cost of delay for Emergency Service Providers. Fire equipment, due to its size and weight, is particularly affected by speed humps. Past studies in Portland found delays per hump of up to 9.4 seconds for the 14-foot designs and 9.2 seconds for 22-foot speed tables. Testing of the offset speed table with median islands made advances in reducing delay for emergency vehicles into the 2-second range but was limited to use on wider streets due to the turning needs of larger fire equipment. This report provides a summary of the testing of the offset speed table with median islands as well as a recent alternative and makes a comparison to speed cushions, a tool often used where emergency response delay is of concern. This investigation was undertaken to evaluate a design that would permit the use of the offset speed hump on designated Emergency Response Routes regardless of the street width.

PORTLAND AND SPEED HUMPS

A Brief History

In 1991 the City of Portland's Office of Transportation (PDOT) undertook a study of speed humps in response to public demand for relief from the excessive and continual increase of traffic speeds. As the result of two years of testing, speed humps and speed tables became standard tools for addressing the problem of speeding on Portland's residential streets. In Phase III of the original 1992 speed hump tests, the Fire Bureau indicated a maximum comfortable speed of 20 mph for the 14-foot speed hump and 25 mph for the 22-foot speed table.[1]

The 14-foot speed hump was adopted for Local Service[2] streets that serve as neither a transit street nor a primary fire response route. The 22-foot speed hump, or table, was designed for Neighborhood Collector[3] streets that serve higher volumes of traffic, to minimize diversion potential, and on streets that are designated transit or primary fire response routes. Speed tables have reduced effect on transit buses and are easier for fire and emergency vehicles to negotiate than the 14-foot speed hump. The 22-foot speed table has proved effective in slowing average 85th percentile speeds along a street to 30 mph. Seventy percent of residents on traffic calmed streets have perceived a change in speed and over 60% perceived a change in traffic volume.[4] The Traffic Calming Program has been installing speed humps since 1992, and to date has installed over 650 speed humps and 180 speed tables. Demand for traffic calming in Portland continues with the current street project backlog exceeding 300 projects. It can be stated with certainty that speed humps will for the foreseeable future be a common tool to slow speeding traffic in Portland.

EMERGENCY RESPONSE ISSUES

Benefits have Costs

With the continued success of speed humps the demand for their use increased greatly. And though the Portland Fire Bureau recognized the community's need for reduced speeding, there began to be significant concern that unbridled installation would soon create a cumulative slowing effect that might compromise emergency response time goals.[5] Friction developed between PDOT and the Portland Fire Bureau over the competing interests of speed reduction and emergency response time. PDOT's offers to mitigate expected slowing on calmed routes with signal pre-emption on higher classified streets assisted some projects but at a relatively high cost for no clearly defined benefit. The two bureaus agreed that there was a lack of knowledge on how much speed tables delayed emergency response equipment. In 1995, PDOT and the Portland Fire Bureau undertook a joint project to evaluate the slowing effects of speed humps and speed tables, as well as traffic circles. Five types of emergency equipment including an ambulance and heavy rescue vehicle up to engines and trucks and a rear-tiller truck were tested.

Delay Results

As expected, smaller and lighter vehicles were generally less affected by speed humps than larger and heavier vehicles. Also as expected, shorter speed humps tended to cause greater delay than longer speed tables. PDOT's testing took into account that delay caused by a particular device is a function of both the vehicle responding and the desired operational speed of that vehicle and so calculated a range of delay for each device. The delay calculated for 22-foot speed tables (10-foot tabletop) ranged from zero seconds to 9.2 seconds.[6]

Table 1. Speed Table Effect on Fire Vehicles[6]

Vehicle	Weight (lb)	Horse-power	Wheelbase	0-40 mph Accel. Time	Lowest Speed, (mph)	Min Delay 25-mph Response	Max Delay 40-mph Response
Rescue 41	na	185	11' 6"	12 sec.	34	0 sec.	1.5 sec.
Squad 1	23,170	275	14' 6"	17 sec.	24	0.4 sec.	3.4 sec.
Engine 18	34,860	185	15' 5"	19 sec.	21	0.8 sec.	5.0 sec.
Truck 1	53,000	450	21' 0"	20 sec.	22	0.6 sec.	4.9 sec.
Truck 4	53,960	450	13' 0"	22 sec.	16	1.8 sec.	7.7 sec.
Truck 41	42,100	350	37' 6"	27 sec.	14	3.0 sec.	9.2 sec.

This new information was well received by both sides. The engineers at PDOT now had hard numbers to work with instead of perceptions. Furthermore, the Portland Fire Bureau could now argue specifically how much speed humps and tables deteriorated their emergency response goals.

In the spring of 1996 a moratorium was placed on the construction of speed tables on all collector level streets and any local street that had previously been designated a fire route by administrative rule. At that time approximately fifteen pending or active projects were placed on hold. City Council then directed PDOT and the Portland Fire Bureau to work through a public process to create policy that would solve the impasse.

POLICY BASED SOLUTIONS

Rules to Live By

One method to address the concerns raised by the Fire Bureau is with a policy-based solution. In February of 1998, PDOT and the Fire Bureau completed development of a new classification of street for addition to the Transportation Element of Portland's Comprehensive

Plan (now the Transportation System Plan – TSP). Primary Emergency Response Routes are designated streets that:

> "Provide a network of emergency response streets that facilitates prompt emergency response. The emergency response classification system shall be used to determine whether traffic slowing devices can be employed, to guide the routing of emergency response vehicles, and to help site future fire stations."[7]

The intent was to identify a grid of streets on which the majority of all emergency calls are accomplished and ensure that increased delay to emergency vehicles on such routes is avoided regardless of the source of the delay.

ENGINEERED SOLUTIONS

Speed Cushions

The policy-based approach addressed current projects and future projects, but left existing streets that already had speed tables and that became Primary Emergency Response (ER) routes alone. For these streets the Portland Fire Bureau agreed to continue with the status quo, and work with PDOT to determine an engineered solution. PDOT recognized the need to address the Fire Bureau's concerns on ER routes, but also had concerns that residents on newly designated ER routes would still need relief from speeding vehicles.

At the time PDOT was aware of the use in Europe of speed cushions to slow auto traffic. Speed cushions, typically made of rubber, were built just wide enough to affect autos, but not too wide so that freight vehicles, larger fire equipment and transit vehicles could straddle all or most of the device. Tests conducted in the UK found that emergency fire equipment could traverse 3-inch speed cushions 10 mph to 20 mph faster than standard speed humps used there. The same report found that cushion width and spacing affected typical driver speeds and that speeds at the devices varied from 15 mph to 26 mph.[8] Mobile Alabama has also found speed cushions to be effective at achieving 85th percentile speeds in the 24 mph to 26 mph range for the typical driver.[9] The City of Austin reported negligible delay to fire equipment as compared to typical speed humps there.[10]

The Portland Fire Bureau considered speed cushions a likely solution to delay issues associated with speed tables and often advocated for their testing. PDOT had considered speed cushions, but significant concerns remained that reducing delay for emergency equipment also meant reduced slowing for typical traffic. Speed cushion use was more common in Europe where fuel prices tend to be significantly higher that fuel prices in the U.S. This price difference was perceived to cause private vehicles in Europe to be more fuel efficient and thus smaller, with narrower wheel tracks, than typical passenger vehicles in the U.S. Narrower passenger vehicles in Europe would mean it is easier to find a speed cushion width that a fire truck or transit vehicle could straddle but that private vehicles could not. The similarity in width of the wheel track of vehicles in the United States was the driving force behind PDOT's reluctance to test speed cushions (Table 2, next page).

Table 2. Typical Vehicle Track Width

Vehicle	Average Track Width*
Private Vehicle – Low[11]	4 ft. 2 in.
Private Vehicle – Average[11]	4 ft. 11 in.
Private Vehicle – High[11]	5 ft. 9 in.
Typical Portland Fire Engine	6 ft. 5 in.
Typical Portland Aerial Ladder Truck	6 ft. 7 in.
Typical Portland Rear-Tiller Truck	6 ft. 8 in.
Typical Tri-Met Transit Bus	6 ft. 3 in.

*Center to Center

Compounding the issue of track width was the common use of dual rear wheels for heavier vehicles like transit buses and fire trucks. Dual rear wheels in heavy vehicles mean the clear space between the wheels of large vehicles more closely matches the track width of sedans and sport-utility vehicles common in the U.S. Finding a speed cushion wide enough to slow most private vehicles and yet narrow enough to permit fire trucks and transit vehicles to pass easily, without overloading those heavier vehicles' rear axles proved difficult. Also, the use of speed cushions means there are intentional gaps, or channels, between devices in a multi-device installation (see Photo 1).

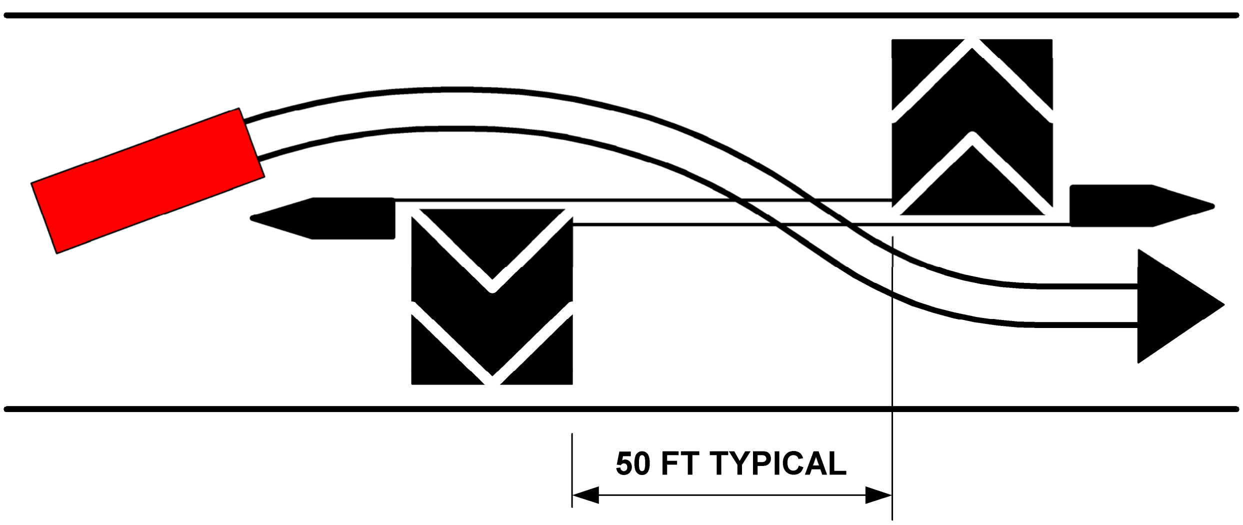
Photo 1. Speed Cushion, Lafayette, LA.

The UK study also found that 45% of drivers aimed for the gaps when traversing speed cushions and noted concern when gaps coincided with street centerlines.[12] Finally, the use of speed cushions and the need for larger vehicles to straddle the devices meant that conflicts with parked vehicles were possible, eliminating the original benefit to using speed cushions.[13]

Offset Speed Table with Median Islands

In 1997 PDOT began testing an alternative to the speed cushion concept. PDOT'S design used a standard speed table that was constructed across only half of a street. The second half of the speed table was constructed downstream of the first and in the opposing lane. As emergency equipment is able to use any portion of the roadway to accomplish a response, the space between the speed table halves permitted emergency vehicles to cross the street centerline and slalom around them in a serpentine pathway (Figure 1). Constructed with the offset speed tables were median islands on the outside approaches to deter civilian drivers from crossing the centerline. In addition, a double yellow centerline was added approaching each island and quadruple yellow centerline with raised pavement markings were added between the speed table halves. The dense pavement markings between the speed table halves gave an illusion that a median continued the entire distance. The addition of the islands and striping was done to deter drivers from mimicking the pathway emergency vehicles could take.

Figure 1. Offset Speed Table with Islands and Emergency Response Path.



Tests of the offset speed table with islands were conducted on two public streets, SE Market and SE 17th, in 1998. The testing of the offset speed hump with islands successfully demonstrated fire truck access speeds of 20-30 miles per hour through the pair of speed tables. Response delay was reduced from a maximum of 9.4 seconds for standard speed tables[6] into the 2-second range.[14] Video of the test site on SE Market showed no indication of confusion on the part of the drivers, nor any violations of drivers trying to avoid the device at any time.[14] The testing also revealed that the offset speed table with median islands has limited application. Street width must be at least 40 feet, curb to curb, to provide for the serpentine path of Emergency Equipment and parking removal is often necessary opposite of each speed table half (see Figure 1). Additionally, where the street is less than 40 feet, transit drivers and other wide vehicle operators may feel uncomfortable traveling between the island and parked cars. Where a 12-foot travel lane between the island and parked cars is not possible, additional removal of parked vehicles adjacent to the island on the speed table side might also be necessary. Many of Portland's Neighborhood Collector streets are less than 40 feet and coincide with Primary Emergency Response Routes. Also, for traffic calming to be considered on Neighborhood Collector streets in Portland, they must have a minimum of 75% residential zoning. Under such conditions, on-street parking demand is generally high, making parking removal politically difficult.

Offset Speed Tables without Median Islands

In 2001 PDOT and the Portland Fire Bureau initiated another round of testing to determine if a speed cushion like device could effectively slow traffic while reducing response delay for emergency vehicles. The concept was to use the standard offset speed hump layout without the islands and adding a speed cushion like channel. In the test a channel was placed through a standard half-street speed table, aligned near the center of the travel lane. The object was to permit a fire truck to place the left side just over the centerline while aligning the right-side wheels with the channel. The hope was that providing the channel would effectively nullify the speed table's effects on large fire equipment.

PDOT constructed a prototype device at the Fire Bureau's training facility (Photo 2). This is a controlled area not subject to general traffic and permitted a variety of vehicles to test the device while data was collected. The primary purpose of this test was to determine what benefit the channeled speed table design provided for emergency vehicle response time. This testing also assisted in answering concerns of PDOT over driver control questions as well as refining the design and evaluating constructability issues.

Photo 2. Offset Speed Hump with Channel Test Object – Looking Upstream.

The test device was constructed at Station 2 the week of July 16, 2001. The test object was a standard 22-foot speed table with 6-foot parabolic approach ramps and a 10-foot flat section with a maximum height of 3 inches. A channel was constructed offset from the centerline resulting in a 6-foot 3-inch wide cushion-like object that emergency equipment could straddle. The edge tapers for the channel and centerline edge were constructed with a 1:2 slope. Formal testing, using eight vehicles, was conducted on July 23, 2001. Each vehicle was driven over the device twice with drivers directed to aim for the channel. For the first run drivers were directed to attain 25 mph before crossing the speed table. For the second run the target speed was 30 mph. In past tests the typical speeds of fire trucks and engines crossing a standard 22-foot speed table varied from 14 mph to 21 mph.[6] The majority of delay at the standard 22-foot speed table is due to the larger fire vehicle's slow acceleration. Attaining typical crossing speeds above 25 mph with the new design would represent a significant reduction in delay for emergency response and was the chosen target speed for a successful test. Each vehicle successfully traversed the test device near or above 25 mph as shown in Table 3.

Table 3. Emergency Vehicle Speed over Offset Speed Table with Channel

		Maximum Speed At Speed Table (mph)	
Vehicle	**Weight**	**First Run 25-mph Goal**	**Second Run 30-mph Goal**
2000 Ford Crown Victoria Police Interceptor	3900 lb.	24	30
2000 Chevrolet Police Camaro	3500 lb.	25	30
2000 Kawasaki KZ 1000 Motorcycle	600 lb.	>26	30
1998 Ford Van – Police Photo Radar Unit	4,700	>25	>30
Fire Rescue 2 - 1994 Ford Fire Rescue	10,500	>25	>30
Engine 2 - 1995 H&W Fire Engine	38,150	25	30
Fire Truck 2	na	30	35
Truck 13 - 1994 Simon LTI, Rear Tiller Fire Truck	58,000	>25	30

* The police vehicles did not attempt to use the channel

Drivers that participated in the testing expressed very favorable comments regarding the channel design and the significant reduction in discomfort for personnel, though concern remained about citizens that might stop on a speed table when an emergency vehicle approaches. The Portland Bureau of Maintenance, who constructs nearly all speed tables in Portland, noted the narrower section between the channel and centerline was labor-intensive to construct and may double the cost of construction over a typical speed table placed with the aid of machines.

The testing also confirmed that the original device proposal might be ineffective for speed reduction. As previously stated, placement of the channel so that the majority of drivers straddle the channel is critical to achieving the desired slowing effect for typical traffic. As originally proposed, and due to current vehicle dimensions, PDOT was unable to identify a channel location that ensured the success of the proposed device for slowing traffic. By placing one set of wheels in the channel a sedan size vehicle driven over the speed table attained a speed of 30 mph without significant discomfort to the driver.

However, the determination that a channel greatly reduced the effectiveness of the speed table for typical traffic even though only one set of wheels could be placed in the channel led to a revised design. In the revised design a half-street speed table without a median or channel would be evaluated. The new proposal would require emergency equipment to cross the standard speed table profile with the right side of the vehicle, but the left side of the vehicle could cross just over the centerline and avoid the speed table profile completely. With the channel removed, vehicles operated by the general public would encounter a standard 22-foot speed table profile, ensuring continued speed reduction. Another advantage to a full half-street speed table is that it can be built faster, and at lower cost, since more of the device could be constructed with mechanical equipment.

A second series of field tests using only the four Fire Bureau vehicles were conducted on July 26, 2001. The second round of testing included target speeds of 20 mph, 25 mph and a free run where the driver picked the speed. The Fire Bureau vehicles ran the same course again, and radar recorded their top speeds while traversing the speed table as follows:

Table 4. Emergency Vehicle Speed With Only Right Half on the Speed Table.

	Maximum Speed At Speed Table (mph)		
Vehicle	**First Run 20-mph Goal**	**Second Run 25-mph Goal**	**Third Run Driver Choice**
Fire Rescue 2	>20	<25	>30
Fire Truck 2	>20	>25	>30
Fire Engine 2	>20	>25	>30
Fire Truck 13, Rear Tiller	>20	>25	>30

As can be seen, the modified design continued to provide excellent travel speed as compared to typical speed table speeds of 14-21 mph for Fire Bureau Equipment.[6] Drivers that participated in the testing continued to express positive comments about their comfort using the speed table as modified.

NEXT STEPS

Early Live Testing

The nearby City of Beaverton installed offset speed tables without islands on SW 87th-Birchwood-Laurelwood in the summer of 2003 (Photo 3, next page). Offset speed tables were chosen due to the designation of the street for emergency response. Before construction of the speed tables the 85th percentile speed was measured at 34 mph in a 30-mph zone with 25% of drivers exceeding the posted speed. After construction the 85th percentile speed reduced to 30 mph with 15% of drivers exceeding the posted speed. Vehicle volume on the street reduced from and average of 5800 vehicles per day (vpd) to 5400 vpd. The offset speed tables were originally constructed with only pavement striping to communicate to drivers to remain on their side of the street due to the weather. Subsequent to construction Beaverton received complaints from local residents about driver circumnavigation of the offset speed tables by crossing the centerline. The City of Beaverton added raised pavement markers with inset reflectors to deter such behavior (see Photo 4) after the weather warmed up in 2004. The City of Beaverton reports that complaints regarding centerline violations are no longer common from local residents.

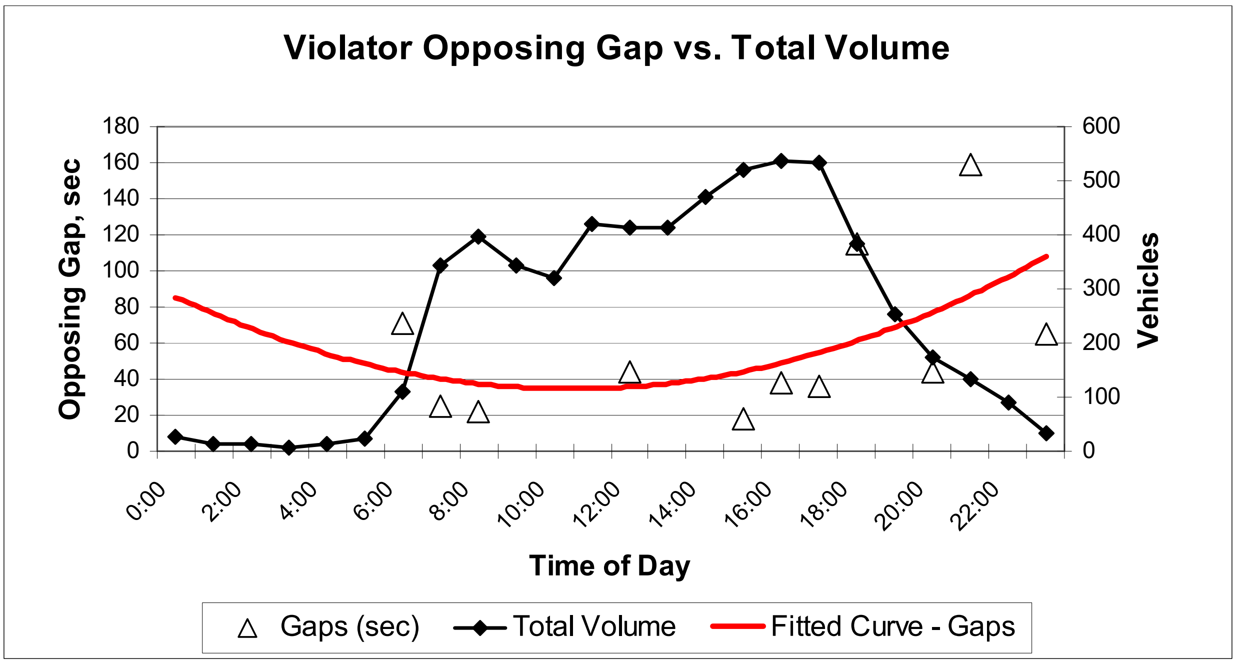
Photo 3. Beaverton Offset Speed Hump – SW 87th Avenue.

Photo 4. Beaverton Offset Speed Hump Centerline RRPMs.

PDOT Testing

It is expected that the offset speed table will be self-regulating in regards to centerline violations and such self-regulation is sensitive to opposing traffic volume. As opposing volumes increase fewer drivers likely to violate a double yellow centerline will do so (see graph 1). PDOT collected video at the Beaverton site to determine the frequency of centerline violations. Approximately 13 vehicles in a 24-hour period violated the centerline to some extent, either completely or partially avoiding the offset speed tables. This represents a violation of 0.22% of the total population of drivers. The average length of time a driver was within a portion of the opposing lane (exposure) during such maneuvers was 2.88 seconds with a standard deviation of 1.13 seconds. The opposing headway gap, the length of time before the next opposing vehicle passed the offset speed table after a violation occurred, averaged 22 seconds with a standard deviation of 10.43 seconds. The exposure and opposing headway analyses are conservative in that data corresponding to opposing gaps in excess of 60 seconds (5 of the 13) were discarded.

Graph 1. Violations versus Traffic Volume



FUTURE RESEARCH

With a speed table that is only constructed to the centerline of a street comes the possibility that civilian drivers will mimic the pathway intended only for emergency service personnel. Opposing vehicle traffic plays a part in making sure drivers stay on their side of the road and slow down. Unknown at this time is what threshold of traffic volume is the minimum needed to ensure that drivers will remain on their side of the street. PDOT is currently seeking a suitable City street to advance testing the offset speed table concept.

SUMMARY

From the outset PDOT has had concerns that efforts to nullify the effect of speed humps for emergency response, as with speed cushions, would also render them ineffectual at reducing speeding. Testing conducted by PDOT and the Portland Fire Bureau successfully showed the ability of the offset speed table design to reduce emergency vehicle delay, especially the largest trucks that normally suffer the greatest delay. A reduction in maximum delay from 4.8 seconds at standard speed tables where the target response speed is 30 mph to the typical 2 second delay at offset speed tables represents a better than 50% reduction in emergency vehicle delay. PDOT is confident that the offset speed table will continue to reduce speeding as effectively as standard speed tables. PDOT was also successful in identifying minor adjustments to the final design to improve constructability. The design changes discussed in this paper, and the cooperation between PDOT and the Portland Fire Bureau to explore a compromise that avoids an all or nothing choice has gone a long way to solving the issue of emergency response delay caused by speed tables.

ACKNOWLEDGEMENTS

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11. NHTSA inertia database available at: www-nrd.nhtsa.dot.gov/vrtc/ca/CAdata.htm
12. Reference 8, page 7.
13. Reference 8, page 8.
14. *Split Speed Bump*, January 1998, prepared by Kathy Mulder, PE, City of Portland, Oregon, Traffic Calming Program.

References 4, 6, 7 and 14 are accessible on the Internet at:
www.portlandtransportation.org/TrafficCalming/reports/REPORTS.HTM#Devices

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Chloe Eudaly Commissioner **Chris Warner** Interim Director

Date: July 18, 2019

To: Chief Sara Boone, Portland Fire and Rescue

From: Lewis Wardrip, City Traffic Engineer

RE: Speed Cushion Redesign Memorandum of Understanding (MOU)

Chief Boone,

The intent of this MOU is to commit in writing our Bureau's agreement on the redesign of PBOT's 'fire-friendly' speed bump, a.k.a. speed cushion, and its future use on Local Service and Neighborhood Collector streets identified as Primary and Secondary Emergency Response routes in the Portland Transportation System Plan.

In response to concerns raised by Portland Fire and Rescue, PBOT has:

- Directed its contractor to correct speed cushions not constructed in conformance with the previous design on SW Stephenson, 35th Avenue to Boones Ferry Road, to conform with the previous design, which work has been completed.

- Redesigned the traversable speed cushion portion of the fire-friendly speed bump in accordance with dimensions provided by PF&R to the design attached as Exhibit 1 – Three Cushion Design and Exhibit 2 – Four Cushion Design. The changes include a wider gap between bump portions, a narrower traversable cushion, and a channel edge taper widened from 6 inches to 9 inches.

- Redesigned the cushion portion based on the following design goals:
    - The front wheels of PF&R emergency apparatus will typically not traverse any raised portion of the speed bump, though the tolerance of the path is minimal, and
    - The rear dual wheels of PF&R emergency apparatus will ride up on a portion of the channel edge taper, depending on how a driver approaches the channels.

PBOT further agrees that changing the existing speed cushions on N Fessenden St. currently under construction to conform to the new practice, including adjustment of the location of one speed cushion located between N Polk Ave and N Tioga Ave, will be pursued with the contractor.

PBOT will monitor the next several speed cushion projects to determine what effect these design revisions have on vehicle speed to determine if they continue to provide speed reduction benefit and provide feedback to PF&R regarding the speed cushions' performance.

PBOT will continue to seek feedback from PF&R regarding future proposed installations of fire-friendly speed bumps on emergency response routes per our current practice.

In witness whereof, the parties to this MOU, through their duly authorized representatives, have executed this MOU on the days and dates set out below, and certify that they have read, understood, and agreed to the terms and conditions of this MOU as set forth herein.

Portland Bureau of Transportation

____

Lewis Wardrip, City Traffic Engineer July 18, 2019

Portland Fire & Rescue

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Sara Boone, Fire Chief July 18, 2019

EXHIBIT 1. NARROW - 3 SPEED CUSHION LAYOUT DESIGN – JULY 12, 2019

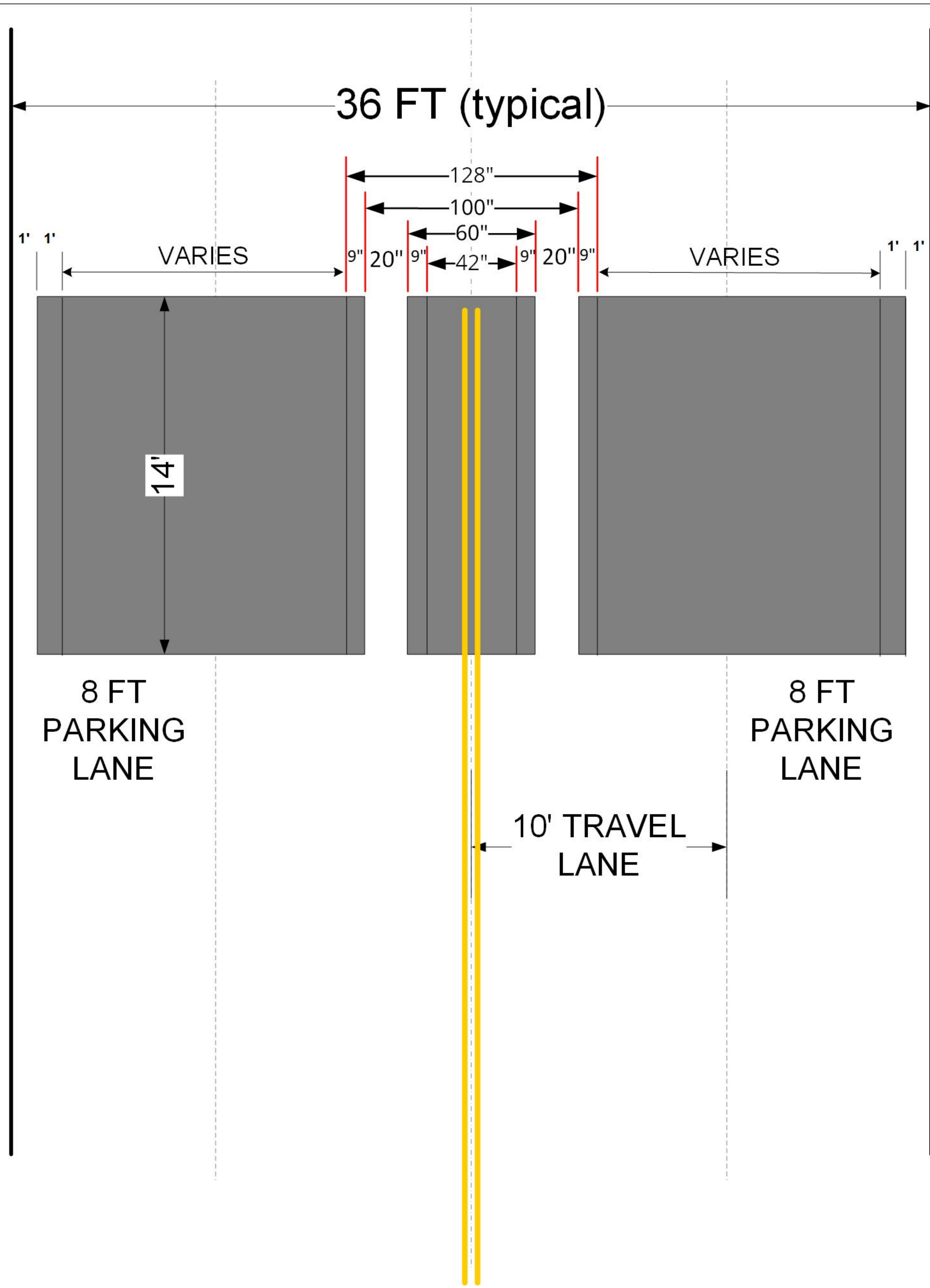
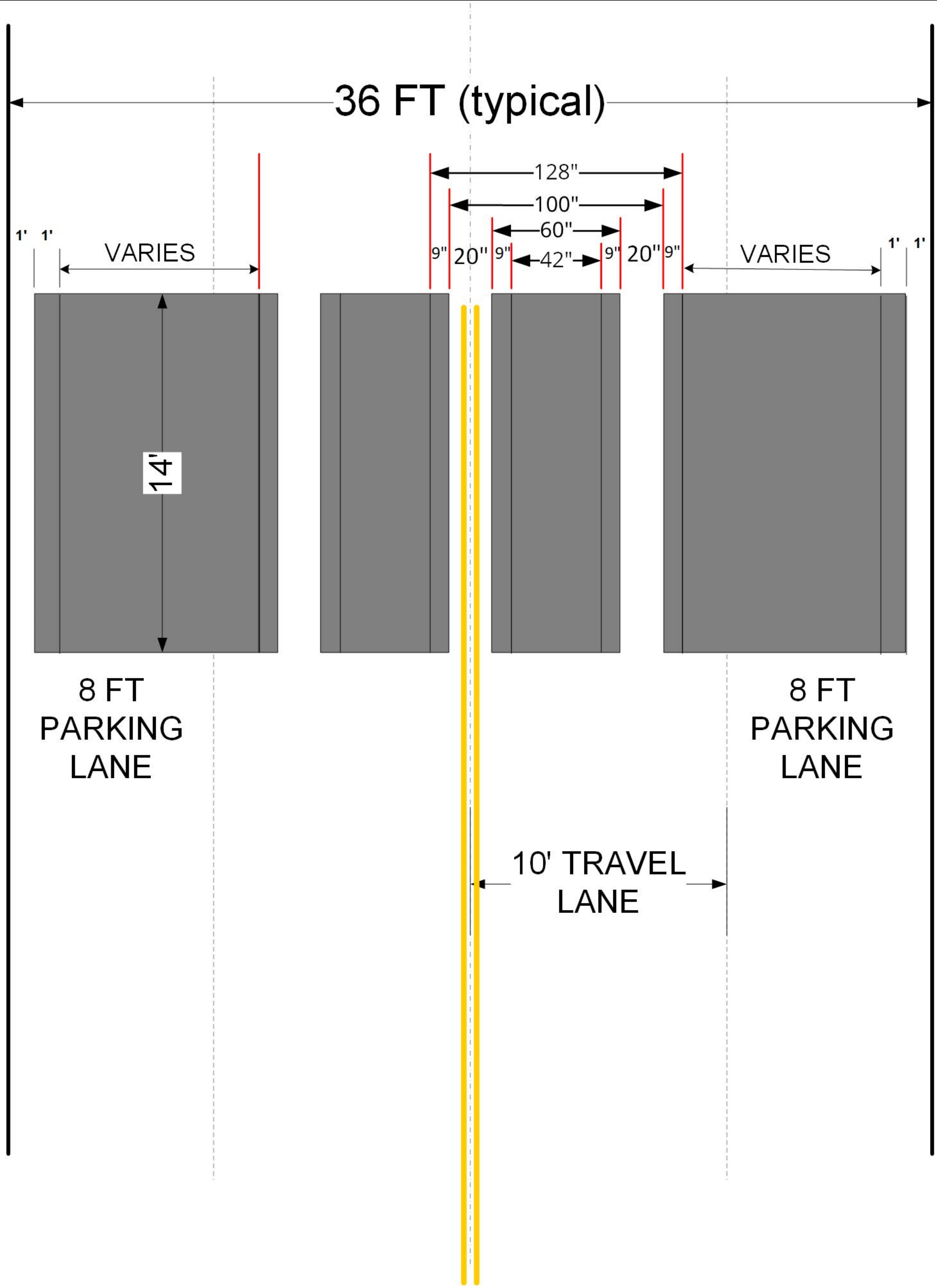


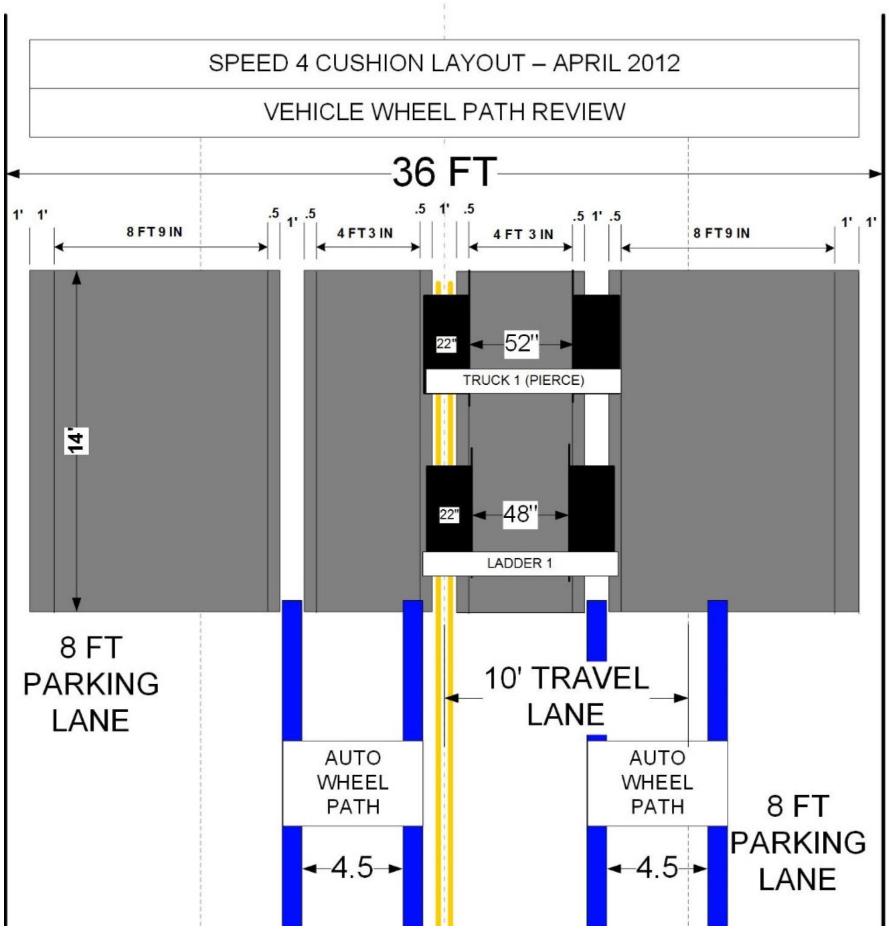
EXHIBIT 2. NARROW - 4 SPEED CUSHION LAYOUT DESIGN – JULY 12, 2019



Speed Cushion Design – Portland, Oregon
Scott Batson

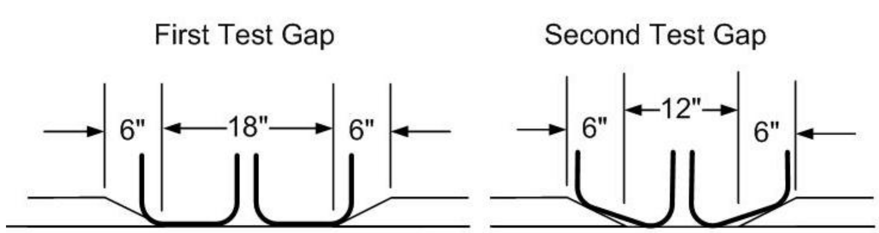
Speed cushion sizing was developed based on measured space between the dual wheels of two representative Portland Fire and Rescue heavy vehicles, Truck 1 and Ladder 1. Figure 1 depicts the expected path for a fire truck or engine and worst-case path for automobile. Automobile wheel path was developed from US DOT data.

Figure 1 – Wheel Path Analysis



The layout of the gap between cushions has had two variations in an attempt to balance fire truck delay reduction with speed reduction effectiveness (Figure 2).

Figure 2 – Channel Design Iterations



Field testing at the training facility confirmed the design parameters.

Engine 2 - Front

Engine 2 – Rear

Ladder 2 - Rear

Tiller 7

Calculation Book Report

Date: November 2, 2021

Technical Owner: Traffic – Scott Batson, P.E.

Calculation Book No. 442 **Standard Drawing No.** P-442

Drawing Title: Multi Cushion Speed Bumps

While the speed bump design is straight forward, it is important to carefully design the placement of the speed bumps so as not to create other problems. Reference the Portland Bureau of Transportation Traffic Design Manual, Volume 1 (link below), for general guidelines for the design and placement of speed bumps.

https://www.portlandoregon.gov/tRANSPORTATION/article/751333

Specific to the application of multi cushion speed bumps, the channels between speed bumps will be utilized by drivers to reduce the discomfort of traversing the bump, so that the slowing effect will be reduced. This will necessitate construction of the speed cushion devices closer to each other to achieve speed reduction similar to that of a standard 14' speed bump. For a target average 85^{th} percentile speed of 25 mph, a spacing of 320'-380' is recommended. For a target average 85^{th} percentile speed of 20 mph, a spacing of 280'-340' is recommended. Closer spacing is recommended where speeding is more significant before project construction. Multi cushion speed bumps on narrow roadways have an increased potential for edge running by drivers such that the edge taper of the outside cushions should be constructed to the edge of roadway pavement.

There are two versions of the multi cushion speed bump.

- A three-section version, where the fire truck straddles the narrow cushion centered on the street centerline, suitable for lower volume roads that are primarily straight in alignment.
- A four-section version, with narrow cushions on each side of the center of a street, such that a fire truck does not have to cross over the centerline, suitable for higher volume roads and roads with horizontal curves.